Journal of Forestry Research (2013) 24(2): 357−360
DOI 10.1007/s11676-013-0360-y

ORIGINAL PAPER

A retrieval and validation method for shelterbelt vegetation fraction

DENG Rong-xin • WANG Wen-juan • LI Ying • ZHAO Dong-bao

Received: 2012-05-02; Accepted: 2012-10-09

Abstract: Shelterbelts are important in defending against natural disaster and maintaining ecological balances in farmland. Understanding of the shelterbelt vegetation fraction is fundamental to regional research of shelterbelts using remote sensing. We used SPOT5 imagery with 10×10m spatial resolution in combination with knowledge of the characteristics of shelterbelts to develop a method for retrieval of the vegetation fraction of shelterbelts by the pixel un-mixing model. We then used the method to retrieve values for shelterbelts in study area. By combining the parameters of photographic images with characteristics of shelterbelts, we developed a method for measuring the vegetation fraction of shelterbelts based on an advanced photographic method. We then measured the actual values to validate the retrieval result. The multiple correlation coefficients between the retrieved and measured values were 0.715. Our retrieval and measuring methods presented in this paper accurately reflect field conditions. We suggest that this method is useful to describe shelterbelt structure using remote sensing.

Keywords: shelterbelt; vegetation fraction retrieval; vegetation fraction measuring; remote sensing

Introduction

Shelterbelts, linear arrays of trees and shrubs planted to create a range of benefits, are a major category of agroforestry practices (Buck et al. 1999). They protect crop fields by reducing wind erosion and improving crop water use, and they increase crop yields and economic returns (Kort 1988). However, the development of shelterbelt construction makes it more difficult to manage the shelterbelts. To efficiently acquire shelterbelt information on regional scales, remote sensing (RS) had been widely applied in shelterbelt research, including shelterbelt extraction (Wiseman et al. 2009) and landscape assessment of shelterbelts (Zhou et al. 1994; Shi et al. 2011). But little research has been undertaken to describe shelterbelt structures by use of RS.

The vegetation fraction, the ratio of vegetation occupying a unit area, is an important parameter in developing climate and ecology models. Accurately acquiring the vegetation fraction of shelterbelts is necessary to study shelterbelt structure and growth by RS.

There are many methods for retrieval of the vegetation fraction, the spectral un-mixing model being the most popular. In this research we used the sub-pixel model combined with knowledge of shelterbelt characteristics and site conditions to improve key parameters of the model. We then developed a method suitable for extracting the vegetation fraction of shelterbelts.

There are many methods for measuring site vegetation fractions, one of which that is widely used is advanced digital photography (White et al. 2000). In the present study we used this method in combination with knowledge of shelterbelt characteristics and the camera parameters to develop a method for measuring the vegetation fraction of shelterbelts. We then used measured values to validate the retrieval values.

Materials and methods

Data source

Shelterbelts are linear objects. By field measurement, the canopy width of shelterbelts in northeast China is about 15 m. So the SPOT5 image with 10 m × 10 m spatial resolution was chosen as our data source. Shelterbelts are distributed in farmland. The spectral features are similar between shelterbelts and crops, and

Fund project: This project was supported by the High-level Personnel Scientific Research Project in North China Institute of Water Resources and Electric Power (No. 201207); the Knowledge Innovation Program of the Chinese Academy Sciences (No. KZCX1-YW-08-02-01), and the National Natural Science Foundation of China (No. 41101373).

DENG Rong-xin ( ) • ZHAO Dong-bao
Institute of Resources and Environment, North China Institute of Water Resources and Electric Power, Zhengzhou 450011, P. R. China.
E-mail: dengrongxin@neigae.ac.cn

WANG Wen-juan • LI Ying
Department of Resources and Environmental Sciences, Henan University of Economics and Law, Zhengzhou 450002, P. R. China.

Corresponding editor: Zhu Hong

this affects the extraction of the shelterbelt from farmland during the growing season. Therefore, the best date to acquire satellite images is in May, when the spectral differences between shelterbelt and crop are greater. The acquiring date of SPOT5 imagery in this study was April 29, 2007.

Site description

The coverage area of one SPOT5 image was selected as our study area, which was located in a wind damage zone of the Songnei Plain. This is a semi-humid zone mainly overlapping Dehui and Nong'an counties of Jilin Province (Fig. 1). This area is important for commercial grain production and typical shelterbelt construction in China. The shelterbelt construction of this area started in the 1950s. After sixty years of construction and management of shelterbelts, especially since the Shelter Forest System Program in the Three North Regions of China in 1978, this area has basically cultivated shelterbelt networks in all suitable farmlands. The shelterbelts are important in ensuring grain production.

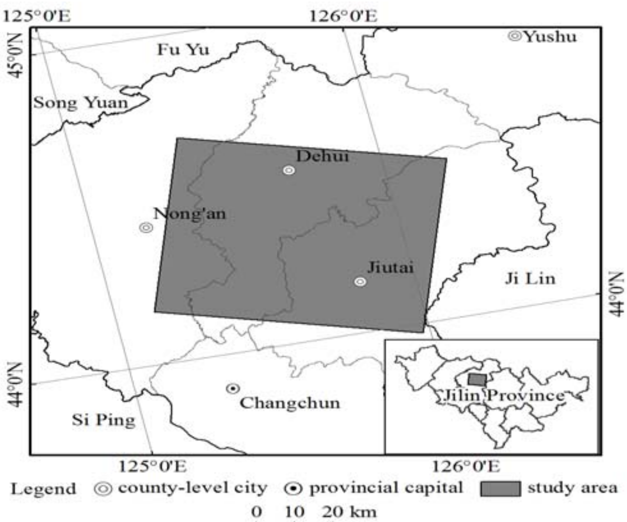

Fig. 1 Location of the study area

Retrieval of the vegetation fraction of shelterbelt

Dimidiate pixel model

The dimidiate pixel model is common in the spectral un-mixing model, and it is a simple and practical remote sensing model (Li et al. 2004; Tian et al. 2004; Chen et al. 2001). The model assumption is that the surface of a pixel is covered with vegetation and non-vegetation. The Normalized Difference Vegetation Index (NDVI) is a type of quantitative value calculated from spectral information of surface objects received from remote sensors and reflects the condition of surface vegetation.

According to the dimidiate pixel model, one pixel of NDVI value can be marked as N_{veg} from green vegetation information and N_{soil} from bare soil information. Hence, the remote sensing model of the estimation of f_c is defined as:

$$f_c = (N - N_{soil})/(N_{veg} - N_{soil}) \tag{1}$$

where, N_{soil} and N_{veg} represent the NDVI values of the bare soil or non-vegetation coverage pixel and a pure vegetation pixel respectively. N is the NDVI value in the equation. Theoretically, the N_{soil} value of most bare soil surfaces approaches zero. However, the range of N_{soil} values is between -0.1 and 0.2 due to the impact of many factors (Carlson et al. 1997; Bradley 2002). N_{veg} represents the maximum value of the pure vegetation pixel. Nevertheless, N_{veg} also changes with time and space due to the effect of different vegetation types. Therefore, the determination of N_{soil} and N_{veg} values is critical to the effectiveness of this model.

Determination of N_{soil} and N_{veg}

There are many methods to obtain end-member values. Scarth et al. (2000) matched the geometric-optical model output to field values, and determined suitable end-member values for use in the spectral un-mixing model. This method had relatively accurate precision, but it required field measurement to ground-truth the image. Zeng et al. (2007) calculated the end-member values with the support of extensive in situ measurements by field spectrometer and Hyperion image. The field measured end-member values were accurate, but because of atmospheric influence and differences in spatial resolution, the values on the satellite image can have more errors than field measurement. Gutman et al. (1998) made the minimum value in the image as N_{soil}, and the maximum value as N_{veg}. However, the image values were easily disturbed by shadows or clouds, resulting in abnormal values in images. Toby et al. (1997) suggested that the ideal N_{veg} is lower than 0.05 as a maximum value. But this was only an experimental value that would be changed for different images. By analyzing the cumulative probability distribution of NDVI about vegetation and soil, Li et al. (2004) chose the NDVI value with confidence of 5% as N_{veg}.

Based on review of the methods mentioned above, the method to determinate end-member values in this study was as follows: We used land use and soil type data, extracted NDVI values of woodland and cropland for each soil type, and chose the NDVI value with given confidence as N_{veg} and N_{soil}.

First, we overlapped land use and soil type data. For N_{soil}, the land use type 'cropland' was taken as a mask to extract NDVI values for each soil type. Then the NDVI values were sorted in descending order. The value with confidence of 0.5% was chosen as N_{soil} for each soil type (Table 1). For N_{veg}, if N_{veg} in each soil type was calculated, the samples of woodland in the study area might be inadequate. Therefore, the NDVI values of cropland for the entire study area were extracted and sorted in ascending order. The value with confidence of 0.5% was chosen as N_{veg}, and this was 0.31 in this study.

Table 1. The N_{soil} of each type of soil

Soil type	Black Soil	Chernozem	Meadow Soil	Alluvial Soil
N_{soil}	0.08	0.08	0.06	0.07

Calculation of vegetation fraction of shelterbelt

A SPOT5 image with 10×10m spatial resolution was chosen as our data source. After geometrical correction and radiometric correction, the NDVI (N) was calculated by formula (2):

$$N = (b1 - b2)/(b1 + b2) \tag{2}$$

where, b_1 is the apparent reflectance of the near-infrared band, b_2 is the apparent reflectance of the red band.

Formula (1) was used to calculate the vegetation fraction of shelterbelts. Where, N_{veg} was 0.31, and N_{soil} can be found in Table 1. The calculated result is shown in Fig. 2.

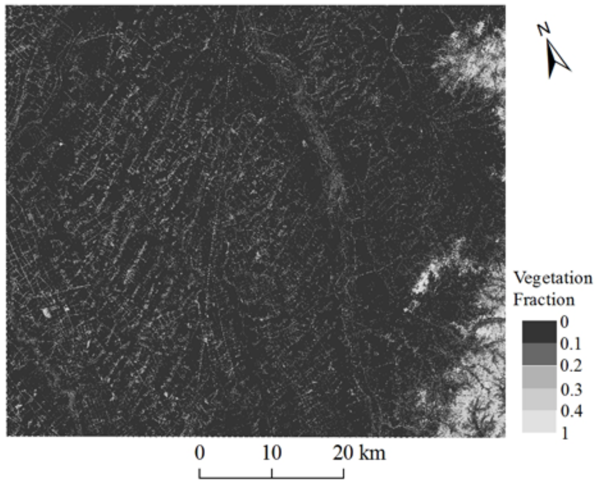

Fig. 2 The retrieval result of vegetation fraction of the shelterbelt

Result and analysis

Validation method

To select a sampling interval required understanding of the area captured on a photograph. The parameters of the camera used in this study are as follows: focal length 35 mm, diagonal direction 62°, horizontal direction 53°, and vertical direction 37°. We assumed tree crowns to be oval-shaped. The parameters of the tree are shown in Fig. 3. We took the minimal visual angle (vertical direction) as standard, the actual length of photo in vertical direction was calculated as: 2 m × 12.5 m× (37°/2) ≈ 8.36 m.

When the digital camera method was used to measure the vegetation fraction, the margin of the photo was distorted. To guarantee the precision of measurements, it is better to remove the margins of photographs. We defined a circle centered on the same spot as a photograph and with a diameter of 5 m as the valid area.

Considering of the spatial resolution of a SPOT5 image and the valid area of a digital photograph, we set the sample interval at 5 m in this study. In Fig. 4, the square shaded area represents the pixel of a satellite image and the circle is the valid area of a digital photograph. The vegetation fraction of each photo within the valid area was computed by threshold, and finally, the mean value of 3×3 vegetation fractions in valid areas was taken as the vegetation of a pixel.

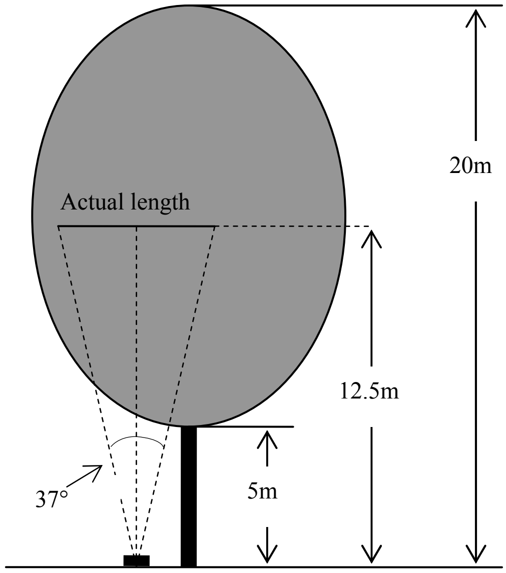

Fig. 3 Model of taking photo of tree

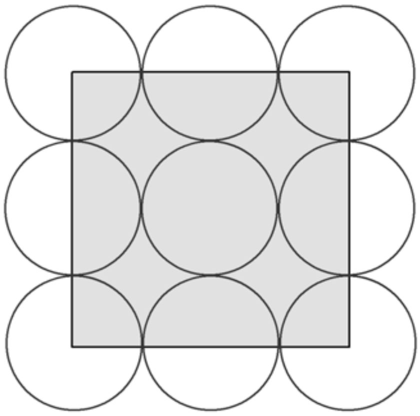

Fig. 4 Sampling interval diagram for measuring the belt vegetation fraction

Results

We chose an entire shelterbelt in our study area as an object, and measured the vegetation fractions on 9 June 2010 using the validation method described above. The measured values and retrieval values are shown in Fig. 5. Absolute error was relatively large and means absolute error was 0.23. Large error was caused mainly by the temporal difference between sample dates: the measured value was acquired in June, and the retrieval value was acquired in late April. Fig. 6 shows that the multiple correlation coefficient between the two values was 0.715, indicating high correlation. Additionally, the fluctuating trends yielded by both methods were consistent, indicating that the retrieval value could reflect the actual vegetation fraction of the shelterbelt.

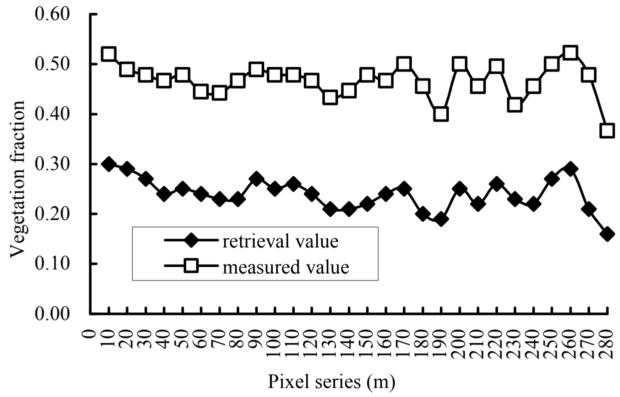

Fig. 5 Comparison between measured vegetation fraction and retrieved value

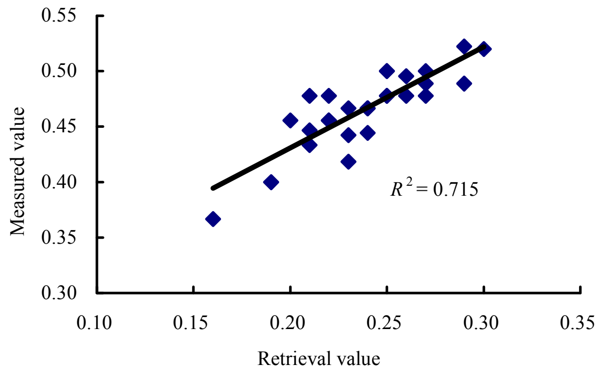

Fig. 6 Correlation between measured vegetation fraction and retrieved value

Conclusions

We used the dimidiate pixel model to retrieve the vegetation fraction of a shelterbelt using SPOT5 image. The key parameters – end-member values were determined using land use and soil type data. To validate the accuracy of the retrieval result, we developed a validation method by computing the valid area of a digital photograph to select a sampling interval. We then used the method to measure an entire shelterbelt in our study area. The retrieval and measurement methods for determining the vegetation fraction of shelterbelts developed in this paper were practicable. The retrieval result reflected the actual value of the vegetation fraction, and this method can provide technology for describing shelterbelt structures through the use of RS.

References

Bradley CR. 2002. The influence of canopy green vegetation fraction on spectral measurements over native tall grass prairie. *Remote Sensing of Environment*, **81**(1): 129–135.

Buck L, Lassoie J. Fernandes E. 1999. *Agroforestry in Sustainable Agricultural Systems*. Boca Raton, FL: CRC Press, p. 416.

Carlson TN, Ripley DA.1997. On the relation between NDVI, fractional vegetation cover, and leaf area index. *Remote Sensing of Environment*, **62**(3): 241–252.

Chen YH, Li XB, Shi PJ, Zhou HL. 2001. Estimating vegetation coverage change using remote sensing data in Haidian district, Beijing. *Acta Phytoecologica Sinica*, **25**(5): 588–593.

Gutman G, Ignatov A. 1998. The derivation of the green vegetation fraction from NOAA/AVHRR data for use in numerical weather prediction models. *International Journal of Remote Sensing*, **19**(8):1533−1543.

Kort J. 1988. Benefits of windbreaks to field and forage crops. *Agriculture, Ecosystems and Environment*, **22/23**: 165−190.

Li MM, Wu BF, Yan CZ, Zhou WF. 2004. Estimation of vegetation fraction in the upper basin of Miyun reservoir by remote sensing. *Resources Science*, **26**(4): 153–159.

Scarth P, Phinn S. 2000. Determining forest structural attributes using an inverted geometric-optical model in mixed Eucalypt forests, southeast Queensland, Australia. *Remote Sensing of Environment*, **71**: 141–157.

Shi XL, Li Y, Deng RX. 2011. A method for spatial heterogeneity evaluation on landscape pattern of farmland shelterbelt networks: A case study in midwest of Jilin province, China. *Chinese Geographical Science*, **21**(1): 48–56.

Song XN, Zhao YS, Liu ZH. 2005. Vegetation/soil synthesis water index using MODIS data. *Journal of China University of Mining & Technology*, **15**(3): 222–226.

Tian J, Yan Y, Chen SB. 2004. The advances in the application of the remote sensing technique to the estimation of vegetation fractional cover. *Remote Sensing for Land and Resources*, **59** (1): 1–5.

Toby NG, David AR. 1997. On the relation between NDVI fractional vegetation cover and leaf area index. *Remote Sensing of Envirenmemt*, **62**: 241–252.

White MA, Asner GP, Nemani RR, Privette JL, Running SW. 2000. Measuring fractional cover and leaf area index in arid ecosystem: Digital camera, radiation transmittance and laser altimetry methods. *Remote Sensing of Environment*, **74**(1): 45–57.

Wiseman G. Kortb J, Walker D. 2009. Quantification of shelterbelt characteristics using high-resolution imagery. *Agriculture, Ecosystems and Environment*, **131**: 111–117.

Zeng Y, Michael ES, Wu BF. 2007. Forest structural variables retrieval using EO-1 Hyperion data in combination with linear spectral unmixing and an inverted geometric-optical model. *Journal of Remote Sensing*, **11**(5): 648–658.

Zhou XH, Sun ZW. 1994. On measuring and evaluating the spatial pattern of shelterbelt networks in landscape. *Acta Ecologica Sinica*, **14** (1): 24–31.